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ABSTRACT

This paper is the last of nine dealing with a "point design" for operations on a large, multi-disciplinary space station. Assumptions of a crew size of six and a large experiment program lead to a design in which most on-board experiments require little astronaut involvement. The men's abilities are applied to a variety of problems, some arising in the improper operation of the machines and others from the development of space flight skills and the performance of a relatively few professional programs where the role of man is well understood or, frankly, experimental. A biomedical/MSF development activity or a second generation solar ATM are typical of activities where man's role will be well understood. Other areas, including bioscience, astronomy, space physics, meteoroids, earth sciences, etc., may vary with the logistics cycle. Manual modes for certain large automated systems will permit experimental test of these facilities in combination with a highly trained on-board operator. It is concluded that the operational point design appears an attractive alternate to concepts in which every experiment must "need the man"; the practicality of the system, of course, rests on a number of configuration, cost, and experiment factors beyond the scope of a study of operations.

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SUBJECT: The Role of Man on a Multi-Disciplinary Space Station. Case 720.

DATE: December 30, 1968

FROM: G. T. Orrok

TECHNICAL MEMORANDUM

I. INTRODUCTION

This paper is the last of nine concerning a study of operations on a multi-disciplinary space station. The purpose of the study was to present an operational "point design" or "one-act play" for planning purposes. The focus is on the roles of the astronauts. In order to do this, it has been necessary to hypothesize the properties of a system. It is believed that the critical assumptions are few and that the following summary discussion of the role of man on the space station depends mainly on those assumptions.

II. THE CRITICAL ASSUMPTIONS

The critical assumptions as we see them were three in number:

1. The space station is fairly large and long-lived. (We initially used the Saturn V Workshop B-2 Study (Ref. 9) as a model.) The time is the mid-70's.

2. The role of the space station is the performance of science and technology in space. The payload is multi-disciplinary; the number of experiments is large and the experiment complement may change drastically with time. (Particular assumptions made for concreteness are typical of recent studies [Refs. 8 and 9]).

3. The crew size is moderate (six men).

III. GENERAL REMARKS

The role of the space station is to perform science and technology in orbit. To set the problem, the men may perform scientific and technological activities, may assist in them, or may assure that they are performed. The jobs should be proportioned between these areas, in accord with our best current understanding, so that the science and technology program advances expeditiously. The authors of the other papers have identified some jobs in all areas. The proportioning is comfortingly like the role of a technical man on Earth. Sleeping, eating and rest, etc. (personal maintenance) dominate the day. There is a reasonable amount of time allotted to making the system go. There is a substantial amount of directed work (e.g., performing the engineering and scientific activities). There is opportunity for occasional creative use of the station facilities. These are described briefly below.

IV. PERSONAL MAINTENANCE

Something between half and two-thirds of a man's time is allotted to personal maintenance. We have assumed long tours of duty, three to six months. We believe that, for long tours of duty, the nominal plan should not schedule more than the eight- to ten-hour work day shown in the Personal Maintenance memorandum (Ref. 3). The energetic worker who wishes to put in a twelve-hour day can be dealt with in the real flight. For planning purposes, he may balance out a less vigorous operator. Personal maintenance includes physical exercise in amounts at least consistent with pre-flight regimes. Normal needs for entertainment must be met; it should be possible to bend the schedule so that astronauts can watch the World Series if they wish. For around-the-clock activity, on the average, two men of the six are available for work at any time (for an eight-hour work day).

V. MAKING THE SYSTEM GO: ROLE OF THE PRINCIPAL INVESTIGATOR

Handling a space station and a large experiment program with an average of two men calls for extensive automation. This makes sense on other grounds. The overall system (NASA, if you like) for expediting space science and technology has a tremendous intellectual resource in its Principal Investigators.* Data management and telemetry are mature arts. We therefore assumed that the investigators would, where possible, operate their experiments remotely; we assumed that they would receive sample data promptly and could respond. This role for the Investigator appears very important in, for instance, stellar astronomy (Ref. 6) and Earth looking (Ref. 7) activities.

It seemed reasonable to assume terrestrial customs for these "observatories", e.g., that there would be a ground observatory director who would be responsible for experiment acceptance and scheduling. Some computer-assisted time-lining

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* In a later, very large space station, one would hope to see a reasonable number of these Principal Investigators or their graduate students in-flight.

would be done; some computation, particularly the interactions with the guidance and navigation systems, etc., would be done on-board.

VI. DATA ASSURANCE AND ASSISTANCE

The automated portion of the experiment payload is reflected in the preliminary mission sequence by a correspondingly modest nominal astronaut activity, expressed as a fraction of an hour per watch. The astronauts provide functions we have called Data Assurance and Assistance.

Data Assurance includes on a daily basis functions like "calibrate, check, adjust," etc., which improve data quality. It includes on an occasional basis functions including "routine maintenance, repair, etc." The astronaut is basically responding to stochastic behavior in the instruments; his actions return the instrument to nominal performance and "assure" the return of data of improved quality.

Assistance includes on a near-daily basis functions inconvenient to automate, such as the change of auxiliaries at the focus of a telescope, changing film, etc. At the ends of the logistics cycle when new instruments are brought to the station, the astronaut may perform manually functions (e.g., installation) which occur rarely in the instrument's life and are not implicit in its normal operation.

It should be emphasized that in this point design, Data Assurance and Assistance take only a modest fraction of the day (perhaps ten percent). They do not require highly specialized training. Needs for the functions occur rarely for a given instrument, so the modest manned activity supports a large number of instruments. Conceptually, this might include 90% of the on-board scientific activity.

VII. BIOMEDICINE/MANNED SPACE FLIGHT DEVELOPMENT

For the Biomedicine memorandum (Ref. 5) it is assumed that the space station followed a 56-day AAP mission, and that the qualification of man for long duration flight is a major objective. One third of the available man-hours are assigned to medical observations. The particular estimates (Ref. 5) are based on the use of the Integrated Medical and Behavioral Laboratory Measurements System (IMBLMS), performing all measurements on all crew members, repeating a cycle in two weeks. A subject and observer are required.

For sensitivity analysis, the medical activity is thought of as decreasing in time, replaced by a program of manned capability extension, including, for instance: EVA development, biotechnology, and human engineering. It seems appropriate that a space station should have a MSF development activity of this size.

VIII. PERFORMANCE OF SCIENTIFIC AND TECHNOLOGICAL ACTIVITIES

In the remainder of the postulated activities, the astronaut appears "in the loop" of the experimental activities of the station. In almost every case he is supplementing automated systems.

The concept of the "nominal day" tends to fail here, because some of the experiment systems are active only for one logistics cycle of the station life. Other activities may require only a few hours a week. This is expressed in part in the time-line of the nominal day by a substantial allotment to "Other Science and Technology." The variety of the work is expressed in other, specific allotments. Bioscience, Solar Astronomy, Film Processing, and the manual modes for the observatories will be discussed.

A. Bioscience

In the initial statement of the point-design, bioscience was selected arbitrarily as an on-board laboratory discipline, typical of others such as space physics or materials science. It was conceived as a discipline which might be pursued for one or two logistics cycles with a specialist astronaut on board. The man is described (Ref. 6) as performing a number of functions (from feeding animals to extracting and analyzing samples) which in totō present substantial problems for automation. It is expected that keeping the specimen colonies alive and healthy may involve unexpected practical problems. In addition, medical development activities (e.g., development of surgical techniques and of sterile analysis techniques [exobiology]) are also identified.

B. Solar Astronomy

Solar astronomy, if performed on a space station, will be a second-generation manned instrument system. Knowing that this system will evolve from the ATM-A, we have for simplicity derived the activity (nine man-hours per day plus manpower for flare-mode) from ATM-A plans (Ref. 7). It includes the direction of small field-of-view instruments to solar features which appear on a rapid time scale, at positions which are relatively unpredictable. Identification of the features requires the recognition of complex patterns. This is a typically human activity. A time allotment of this size is reasonable for a space station; in the long run, solar astronomy might be supplanted by other disciplines.

C. Film Processing

This loosely defined mode was placed arbitrarily under astronomy (Ref. 7) in the associated papers. More generally applicable, it includes any manual activity helpful for on-board film processing, tape stowage, etc. and, more important, the scanning of data to select sample frames or portions of frames to be returned by telemetry to the Principal Investigators for quick-look information. This represents a capability for intelligent data compression.* The data selection criteria can be arbitrary; the number of frames which can be examined is, however, bounded, and unless the selection criteria are obvious, fairly small.

D. Manual Modes for the Observatories

Perhaps as important as the identified, daily blocks of time, are the occasional activities and certain, potential activities which are identified in the attached papers. We certainly do not know at this time what man-machine systems are optimum, even for a six-man space station. If we did know, the optima will certainly shift as successor space stations are built. It is important, then, that we have a capability for learning built into the early station. An example arises in the manual modes for the "observatories."

Zill (Ref. 7) recommends that a control console with full monitoring and control capability be available for the postulated 1 meter stellar telescope. The telescope's normal mode is automated. The console will assist in any maintenance activities, permit back-up in the case of failures in the link to the Principal Investigators, and in the instance that, for one logistics cycle, an astronomer is in-flight, permit him (in accord with the telescope schedule) to work directly with it. Elam's treatment of the Earth-looking facility (Ref. 8) is similar.

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* There is an implicit assumption that (a) data acquisition rates will exceed telemetry rates and (b) some data will be returned much faster than other data. These seem reasonable for any general purpose space station.

There is a hypothesis here that certain studies of an exploratory nature move best with a minimum of automated links between the data and the observer. Most studies are not exploratory. Data and partial understanding exist, and the efficient course is to harness a large number of Principal Investigators and let them direct the instruments via automated sequencing in a rapid and varied experiments program. The exploratory measurements should be less regimented. In the point design, we assume that skilled astronauts can operate the major facilities directly for a small fraction of the station life. The impact on configuration* is helpful (as regards maintenance and back-up capability). Hopefully, this will both attract better-trained specialists into the astronaut population and lead to a better understanding for the design of succeeding facilities.

IX. SUMMARY

The associated papers and this have presented a varied and, we believe, attractive role for man on a large multi-disciplinary space station. It is important that we have attempted to use man in space as on Earth. Men bring to the system perception, intelligence and adaptive action. They bring a substantial cost in sleep time, in food and air, and in the capability for weariness and boredom. The assumptions of small crew size (six) and a large experiment program led us to postulate a schedule where the men's abilities can be applied to a variety of problems, some arising in the improper operation of machines and others from the development of space flight skills and the performance of scientific and technological experiments. Aside from personal maintenance, the bulk of crew activity centers on areas (biomedicine/MSF development, Solar Astronomy, bioscience, etc.) where human roles are well understood. Automation permits the Principal Investigators on the ground to direct most of the remaining activity. The flight man-power complements this, and is not a scheduling bottleneck. At the same time, the provision of manual modes, helpful for on-board maintenance and the back-up of automated systems, permits the harnessing of the higher faculties of specialist astronauts; it further offers experience for the design of future space stations.

X. CONCLUSIONS

As a point-design, this study has been more suited to the raising of questions than to reaching conclusions or recommendations. We believe the following to be pertinent results:

* High resolution telescope operations must of course be isolated from spacecraft vibration sources including man.

1. This operational point design, in which most on-board experiments require little astronaut involvement, is an attractive alternate to concepts where every experiment must "need the man."

2. Then, the scheduling of the men can be flexible. "Needs" arise when systems or experiments malfunction or require special adjustments; they can be met, irregularly, as they arise. The major scientific and technological return of the station is decoupled from the detailed astronaut timeline.

3. Major instrument clusters, astronomical, Earth looking, etc., should have automated and manual modes, with the usefulness of the latter to be determined by experience.

4. It is not unreasonable that the body of astronaut working time should be devoted to a few professional programs where the role of man is well understood or frankly experimental. Biomedicine/MSF development will be one; the others, scientific or engineering in nature, will vary with the logistics cycle and with the professional training of the astronaut; bioscience, astronomy, physics, materials science, earth sciences, etc., are possibilities. These activities are a small part of the total station activities.

5. We suspect that a modification of the point design would still be attractive for crew sizes of perhaps 3 to 9; but that the system concept would be less attractive for crews smaller or much larger.

6. The practicality of this point design rests on a number of factors beyond the scope of a study of operations. The cost of the large experiment program and the practicality of design for maintenance and repair may be the most significant factors.

G. Timothy Orrok

1011-GTO-cb G. T. Orrok

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